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REPORT OF FINDINGS: ALASKA MARITIME NATIONAL WILDLIFE REFUGE

WOMENS BAY CONTAMINANT STUDY

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INTRODUCTION

The Alaska National Interest Lands Conservation Act (Act) created the Alaska Maritime National Wildlife Refuge (Refuge), and mandated the management of 2,500 islands, reefs, pinnacles and tidelands. The Act specified that those submerged lands and water column around Kodiak Island that were retained in federal ownership at the time of statehood would become a part of the Refuge (Figure 1). One of the significant properties under this provision is the former Womens Bay Naval Reservation. The reserve was originally established by Executive Order 8278 of October 20, 1939, and amended by Public Land Order 1182 on July 7, 1955. Thus the Refuge boundaries include portions of St. Paul Harbor and all of Gibson Cove to the north, all of Womens Bay, and proceeds southward past Holiday Beach on Middle Bay (Figure 2).

Womens Bay is located about six miles southwest of the city of Kodiak. The outer coastline of Womens Bay consists of cliffs except at Nyman Peninsula and mouths of major streams. An extensive mudflat fed by four streams occurs at the head of the bay.

Womens Bay provides valuable habitat to a variety of fish and wildlife species. Salonie, Panamaroff, Russian and Sargeant Creeks at the head of Womens Bay support runs of pink (_Oncorhynchus gorbuscha_), chum (_O. keta_), and coho salmon (_O. kisutch_) and resident and anadromous Dolly Varden (_Salvelinus malma_). Near the city of Kodiak, the Buskin River provides habitat for pink, sockeye (_O. nerka_), coho and chum salmon, steelhead trout (_Salmo gairdneri_) and Dolly Varden. In the spring salmon out-migrants feed in the bay before moving out to sea.

A commercial fishery for Pacific herring (_Clupea harengus pallasi_) occurs in Womens Bay also; spawning habitat (kelp beds) are scattered throughout the bay. A Dungeness crab (_Cancer magister_) subsistence and commercial fishery also occurs in the bay. King (_Paralithodes camtschatica_) and tanner crabs (_Chionoecetes bairdi_) move in and out of the bay to feed and mate. Population sampling indicates that the bay contains king and tanner crab in all life stages and contributes adult males to the Chiniak Bay fishery. The bay also serves as a nursery area for juvenile shrimp (_Pandalus_ spp.).

Important seabird forage fishes occurring in Womens Bay include sandlance (_Ammodytes hexapterus_) and capelin (_Mallotus villosus_). In May or June, capelin spawn at Buskin and Holiday beaches during spring tides. This event also supports a local sports fishery. Six seabird colonies in the bay have been monitored by the U.S. Fish and Wildlife Service (Service). Availability of forage fish is believed to be strongly correlated to reproductive rates of these colonies.

Womens Bay is used as a staging area by several hundred to a thousand waterfowl, with northern pintails (Anas acuta) being most common. Seaducks winter in the bay, but there is also a spring migration of greater scaup (Aythya marila), common goldeneye (Bucephala clangula), buffleheads (B. albeola) and scoters (Melanitta spp.) with peak populations occurring in April. A wide variety of ducks and shorebirds nest adjacent to the mudflats at the head of the bay and on islands in the bay.

The Alaska Department of Fish and Game (1973) considers the southeast corner of Womens Bay, in the vicinity of Mary Island and Bruhn Point, a high density area for harbor seals (Phoca vitulina). Brown bears (Ursus arctos) are seasonally attracted to Salonie Creek where they feed on spawning salmon.

Activities and Potential Contaminant Sources

The potential for contaminant problems has existed for decades, and will likely increase in the future. Womens Bay has been and continues to be affected by industrial development, military facilities, spills of organic materials and non-point source activities. Numerous seafood processors operate along St. Paul Harbor and Near Island Channel. Eight processors received National Pollutant Discharge Elimination System (NPDES) permits in 1986; they may collectively discharge 5,888,000 gallons of wastewater daily. Two additional facilities, Kodiak Reduction Inc. and Cook Inlet Processing, Inc. have recently been rennovated and are expected to commence operations soon in/near Gibson Cove. Prior to rennovation the former facility operated without a valid NPDES permit for nearly ten years. Pollution of Gibson Cove was sufficiently controversial to require intervention by the State of Alaska Ombudsman's office.

The Naval Base on Nyman Peninsula was converted to a Coast Guard Facility in the 1940s; it is the largest Coast Guard Base in Alaska and occupies virtually the entire peninsula. Numerous documented hydrocarbon spills and leaks have occurred at and near the facility in the last decade. Following a detailed inspection, the U.S. Environmental Protection Agency mandated that many storage tanks and infrastructures be replaced. The U.S. Geological Survey simultaneously investigated potential ground water contamination from improperly stored/disposed materials.

Womens Bay is the site of a military dumping ground that was presumably utilized during and after World War II. The Service presently has no information concerning the period of use, nor the amounts and types of materials disposed in these waters.

An active Coast Guard landfill and abandoned U.S. Navy landfill produce leachates which eventually enter the Buskin River. The

Buskin River, in turn, empties into Refuge waters. A Coast Guard (contracted) study stated that previous asbestos disposal was no longer a problem, but that turbidity, biochemical oxygen demand, and phenol were noticeably elevated (EMPS Engineering, 1984). The report recommended remedial measures for both the Navy and Coast Guard landfills to reduce leachate input to the Buskin River.

Sporadic grab samples taken by federal and state agencies have indicated elevated levels of contaminants at specific sites and specific points in time. However, data have not allowed general conclusions about overall quality of Refuge waters and their ability to support fish and wildlife resources.

Future development plans within Womens Bay include expansion of the Coast Guard facility, expansion of dock facilities for a freight transfer company, construction of dry-dock boat repair facilities, and expanded operation of seafood processing facilities. Existing and future developments have the potential to pose significant cumulative impacts to the fish and wildlife resources of the area. (Some of the potential contaminant inputs are mapped and described in Figure 3 and Table 1.) This study was undertaken to assess the present levels of contaminants identifiable in Womens Bay.

METHODS AND MATERIALS

Study Area

Figure 3 shows the location of some major potential contaminant sources; Figure 4 displays the sample zones and the sites sampled. Appendices A and B list all samples by zone and provide relevant specific information for each sample. The selection of valid control sites was impractical since it was not known if, how far, or in which direction(s) contaminants may have dispersed. Rather than taking control samples a significant distance from the study area and **assuming** they were valid for all sites, the investigators chose to compare results to criteria as described in a later section of this report (Data Interpretation). Descriptions of the sampling zones follow.

Zone 1 - Mouth of Buskin River: Three sediment samples were taken approximately 200 meters offshore; two sediment samples were taken 200 meters upstream of the river mouth; four sediment samples were taken 400 meters upstream of the river mouth. Six biota samples were collected for analyses and included 1 flounder, 9 hermit crabs, 1 hairy crab, 20 snails, 2 cockles and 4 dungeness crabs. The cockles and dungeness crabs were taken from Sandy Beach Cove, immediately south of Gibson Cove.

Zone 2 - Womens Bay, Southern Mud Flats: Twenty biota samples were taken for analyses from the mud flats, including 54 clams and 38 mussels. Collections were made by hand at low tide.

Zone 3 - Womens Bay, Southern Shelf: Twenty-six sediment samples were taken on the shelf between Frye Point and Mary Island. A shallow, mid-level and deep sample were taken across three transects; a shallow and deep sample were taken for two other transects (that were positioned between the previous three transects). Depths ranged from six to sixteen meters. Two biota samples were collected. Three hairy crabs and one dungeness crab were captured by divers in eight meters of water.

Zone 4 - Nyman Peninsula, Southeast: Six samples of eelgrass (with attached sediment) were collected by divers at water depths of 2-3 meters. Three hairy crabs were also collected by the divers at the same location.

Zone 5 - North Womens Bay Bottom: Twelve sediment samples were taken from a zone around the perimeter of the enclosed portion (northwest arm) of Womens Bay. Depths ranged from 2-16 meters. Six biota samples were collected by divers and included 11 tanner and 2 hairy crabs.

Zone 6 - North Womens Bay Intertidal: Eight samples (total of 97 mussels) were collected from the extreme northeast corner of the enclosed portion of Womens Bay. This area had been boomed due to a fuel leak (JP-5) from the adjacent uplands. Mussels were taken from the area immediately outside of the containment booms.

Zone 7 - Zaimka Island Gut: Two biota samples (total of four hairy crabs) were collected by divers at low tide; water depth was approximately three meters.

Field Procedures

All sediment was collected with stainless steel equipment - spoons for subaerial, Ponar dredge for submarine. Samples were placed in 250-ml, polyethylene jars with Teflon-lined covers, and frozen until analyses. Clams were dug at low tide with a stainless steel shovel. The single flounder sample was collected with hook and line; all other biota were collected by hand. Samples of flora (eelgrass) with attached sediment was double-bagged in ziplock containers, labelled and frozen until analyses. Faunal samples were wrapped in foil, sealed in ziplock containers, labelled and frozen until analyses.

Analytical Procedures

Standard techniques of atomic absorption and inductively coupled plasma spectrometry were utilized by Versar, Inc. to determine concentrations of metals. Organochlorines and polycyclic aromatic hydrocarbons (PAHs) were analyzed by Texas A and M Research Foundation. Table 2 lists all the chemical compounds and inorganics analyzed. The lower level of detection for the polychlorinated biphenyls (PCBs) is 0.5 parts per million (ppm); that for all other organochlorines is 0.02 ppm. The detection limit for PAHs is 0.01 ppm. Detection levels for inorganic elements vary for each sample and element.

All PAHs and organochlorine concentrations are expressed in ppm and were determined on a wet weight (ww) basis. Inorganic values are also expressed in ppm, but were determined on a dry weight (dw) basis, unless otherwise indicated.

The quality assurance report of the U.S. Fish and Wildlife Service's Patuxent Laboratory stated that the accuracy and precision of all analyses were generally acceptable for most analytes. However, selenium and mercury results are biased low. The bias in selenium data is estimated at -30% ; that for mercury at -25%.

RESULTS

Complete sets of raw data are on file at the Alaska Maritime National Wildlife Refuge and the Ecological Services Anchorage offices. All raw, untabulated, analytical data are available upon request. Raw data for inorganic elements are tabulated by element in Appendix C. Appendix D provides a characterization of each contaminant-category found at the various study sites. The overview is provided to assist in comprehending the significance of the analytical results, conclusions and recommendations.

Organochlorines

Organochlorine analytes were detected in only two samples. One sediment sample (one-fourth mile upstream of the mouth of the Buskin River, sample 6B) contained 1.62 ppm of total PCBs. One composite sample of four tanner crabs (collected from the northeast portion of Womens Bay, sample 51B) contained whole body residues of 1.73 ppm total PCBs.

Polycyclic Aromatic Hydrocarbons

Twenty-two of the 57 total samples were completely free of PAHs; 20 samples had detectable, but relatively low, concentrations of various PAHs; 15 samples contained one or more analytes that exceeded detection limits by an order of magnitude or more (Table 3). The latter set is obviously of greatest concern, and includes the four samples taken one-fourth mile upstream of the mouth of the Buskin River, and every sediment sample (total of nine) taken adjacent to Nyman Peninsula. Phenanthrene, fluoranthene and pyrene were the most commonly elevated analytes in this set of data - each being elevated in nine of thirteen samples. Sample 43B in zone 5 contained the most analytes in highest concentrations.

Inorganics

Trace metal concentrations in sediment samples (see Appendix C) were all within normal ranges. In no case did a sample exceed the action level criteria (Appendix E). Antimony and selenium were rarely detected. Metals in biota were also within expected ranges. Vegetation samples contained higher concentrations of several elements (chromium, iron, lead, manganese, nickel) as compared to fauna. However, in no case did a sample exceed the action level criteria (discussed below).

DISCUSSION

Data Interpretation

The process of interpreting chemical analyses is aimed at addressing the question "Do the sample data indicate a problem exists?" In its simplest form this act would appear to consist of comparing each sample datum with a list of action levels or threshold levels (= criteria), above which a problem - albeit undefined - exists. Indeed, this would be ideal. However, a variety of problems impede this approach.

In the cases of water and soil/sediment, the total amount of a chemical reported for a sample is not synonymous with the amount that is (biologically) available. The latter is strongly influenced by a complex suite of physical, chemical and biological factors (e.g. pH, Eh, hardness, alkalinity, salinity, concentration of organic matter, texture). One never has all relevant information for each sample that would allow adjustment of calculated values prior to comparison with a list of criteria (Long and Morgan, 1990; Shea, 1988).

In the case of tissue samples, a different criterion may exist for each species, as well as the particular tissue within that species (e.g. liver vs. kidney vs. muscle vs. whole body homogenate). A sublethal criterion (e.g. avoidance, impaired growth, impaired reproductive success) is much lower than a criterion for safe consumption levels or acute mortality. Moreover, several reviews have warned that using tissue levels of metals as indicators of pollution is not justifiable (Jenkins, 1980a; Mance, 1987; Phillips, 1977; Stokes, 1979). Phillips (1980) emphasized this point by stating: "...no study has yet been reported in which an indisputable correlation between levels of metals in the fish and those in the environment was demonstrated." These and other problems with developing a single set of rigid criteria are thoroughly discussed in Long and Morgan (1990) and Soholt, et al (1981).

Notwithstanding all the above problems, a partial set of criteria has been subjectively constructed by amalgamating a variety of information including: Environmental Protection Agency's water quality criteria; review papers/series that offer lists of "action levels;" U.S. Food and Drug Administration's action levels for poisonous or deleterious substances in human food; World Health Organization's list of water quality criteria; and sundry literature dealing with a biological effect of one, a few, or a group of individual chemicals. As many of the above sources as time allowed were reviewed prior to finalizing the criteria (Appendices E-G). Our review of information is an ongoing process; thus, the criteria are subject to change in the future.

The approach to interpretation consists of a 4-step process, essentially comparing each laboratory-reported value to a series of screens:

(1) Background or control samples taken from the study area
(2) The subjective set of criteria (Appendices E-G)
(3) Literature values listing averages and ranges for Alaska (Gough, et al., 1988)
(4) Literature values listing averages and ranges on a worldwide basis (Fortescue, 1980)

In general, we did not consider a sample value problematical unless it exceeded one order of magnitude of the appropriate screen(s). This is a common strategy designed to provide a buffer for a variety of sources of inherent variance, principally site specificity and laboratory methodology.

Organochlorines

Although two samples contained detectable levels of PCBs, neither exceeded the action levels (Appendices F and G). The sample from the mouth of the Buskin River (6B) was one of four taken in the same vicinity. The need for concern is reduced since none of the other three contained detectable concentrations. The crab sample (51B) was a composite of four crabs. It is impossible to determine if the PCBs were present in only one (or more) of the crabs. It must also be noted that crabs are quite mobile, and thus do not help delineate a potential geographical source of input. Since no other sample of biota - individual or pooled - contained detectable levels of PCBs, concern is reduced.

Polycyclic Aromatic Hydrocarbons

Petroleum products and combustion of fossil fuels are primary sources of PAHs, which are of concern because they may be carcinogenic and/or mutagenic. Elevated levels of PAHs were found in all four sediment samples taken from the mouth of the Buskin River (Zone 1). This is an expected result given (1) the river is a natural funnelling mechanism for all upstream sources, and (2) the potential upstream sources are numerous (landfills, adjacent development, etc.). All sediment samples taken adjacent to Nyman Peninsula contained elevated concentrations. This is probably the result of inputs by the variety of sources located on the periphery of the peninsula (see Figure 3 and Table 1 for specific locations and descriptions). Moreover, a chronic leak of jet fuel had occurred in the area (closest to sample sites 41B, 42B, 43B and 44B) for four months prior to our sampling. As shown in Table 3, these sites showed the largest number of analytes at elevated levels. It is noteworthy that elevated levels of PAHs were not present in the biota samples from the general vicinity, indicating that the sediments may be acting as a sink for the materials.

Inorganics

All concentrations of inorganics were within expected ranges; there were no results indicative of excessive inputs to the marine system. Many elements are normally more abundant in marine biota than in their freshwater counterparts. Arsenic residues, for example, are frequently found up to 100 ppm; these concentrations present little hazard to the organism or its consumers because it mostly occurs as arsenobetaine (Eisler, 1988). The 21.2 ppm of cadmium in the snail sample (number 11) is elevated relative to other biota. However, this is not a problem since higher levels are characteristic of a secondary consumer. The value is an order of magnitude below that found in a congener from a polluted estuary in England (Butterworth, et al., 1972).

CONCLUSIONS AND RECOMMENDATIONS

Data indicate that selected PAHs are somewhat elevated near Nyman Peninsula. The geographic extent of the contaminants is unknown due to the limited sampling. The degree of elevation is not alarming; indeed, it is to be expected given the variety and duration of petroleum inputs to the marine system. Some (unpredictable) levels of input will certainly continue in the foreseeable future, and it would be prudent to conduct additional and more extensive monitoring on a regular basis. Sampling should occur every two years at a minimum, and be adjusted as results and known inputs of contaminants dictate. If financial constraints exist, tissue analyses should receive lower priority than sediment analyses. Prior to future sampling, Refuge staff must submit a study plan to the Regional Contaminants Coordinator to secure funding.

REFERENCES

Butterworth, J., Lester, P., and G. Nickless. 1972. Distribution of heavy metals in the Severn Estuary. Mar. Pollut. Bull. 3: 72-74.

EMPS Engineering. 1984. Sanitary landfill study at U.S. Coast Guard Base in Kodiak, Alaska. Contract No. DTCG 35-83-C-00191.

Fortescue, J. A. C. 1980. Environmental Geochemistry: A Holistic Approach. Springer - Verlag, New york. 347 pp.

Gough, L. P., Severson, R. C. and H. T. Shacklette. 1988. Element Concentrations in Soils and Other Surficial Materials of Alaska. U.S. Geol. Survey Prof.Paper 1458. 53 pp.

Jenkins, D. W. 1980. Biological Monitoring of Toxic Trace Metals. Volume I, Biological Monitoring and Surveillance. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-089, NTIS PB81-103475. September. 215 pp.

Long, Edward R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Tech. Mem. NOS OMA 52. 175 pp.

Mance, Geoffery. 1987. Pollution Threat of Heavy Metals in Aquatic Environments. Elsevier Applied Science, London. 363 pp.

Phillips, D. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments - a review. Environ. Pollut. 13: 281-317.

Phillips, D. 1980. Toxicity and Accumulation of Cadmium in Marine and Estuarine Biota. Chap. 12 in J. Nriagu (Ed.) Cadmium in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.

Shea, D. 1988. Developing national sediment quality criteria. Environ. Sci. Technol. 22(11): 1256 - 1261.

Soholt, L., Harris, V., Knight, M., Siskind, B. and D. Wyman. 1981. Coal Combustion Waste Manual: Evaluating Impacts to Fish and Wildlife. U.S. Fish and Wildlife Service, Biological Services Program, National Power Plant Team, FWS/OBS-81/05. 150 pp.

Stokes, P. 1979. Copper Accumulations in Freshwater Biota. Chap. 12 in J. Nriagu (Ed.) Copper in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.
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Table 1. Descriptions of potential contaminant sources

LOCUS	DESCRIPTION
A	East side of Nyman Peninsula. Old Navy dump, believed to be mostly planes, metal scrap, etc. Cleaned in 1985 by a Corps of Engineers' project.
B	Bruhn Point on southwest side of Mary Island. Navy dump used until about 1970; mostly domestic waste, scrap metal, auto bodies, etc.
C	Russian Creek Mouth (Bell Flats); military landfill operated from early 1940s until 1982. Believed to be mostly scrap metal. Municipality of Kodiak started a cleanup, but never completed. A Corps of Engineers' project to finish the cleanup is still in progress.
D	A fish/crab/deer-cleaning shed with entrails emptying directly into the bay; four large boiling pots for crabs.
E	The "Valley of 10,000 Barrels" near Boy Scout Lake. Period of first use is unknown. Navy contracted to have it covered over in 1971; believed to be mostly asphalt barrels. Further down the road is a large scrap metal dump that was covered also.
F	Old outfall for powerplant which could be collecting/ disgorging groundwater and attendant contaminants. Six to ten other outfalls in varying states of deterioration also scattered around Nyman Peninsula, but purportedly plugged/blocked.
G	"Pad 95" was used for storage of transformers. Labelled as restored, but transformers presently stacked in open (behind chain link fence) about 20 meters from shoreline.
H	Barrel disposal area; contents and numbers unknown. Used at least forty years ago by Navy; could be leaching into Buskin Lake, the source of drinking water for the extant Coast Guard Station and Kodiak National Wildlife Refuge.
J	An active barrel storage area measuring approximately 20 meters by 30 meters. It is marked and signed (warnings).
K	Marginal Pier has deteriorated and is no longer used for docking. Divers have seen > 50 barrels on the bottom in this area; believed to be tar/asphalt and other unknowns.

Table 1. (cont.)

L Freye Point is the site of low-level radioisotope storage (bunker with a chain link fence). Anecdotal information indicates that protective containers and a short half-life allow the area to be considered a "non-problem."

M Finney Beach (a.k.a. Jewel Beach) was used for general disposal of concrete and scrap metal for an unknown period of time.

N Anecdotal information indicates a tanker ran aground in the vicinity (no date); fuel was pumped ashore into a swale for storage, where it sat until buried by a Navy contract which handled the "Valley of 10,000 barrels."

P Coast Guard golf course receiving chemical insect control, moss control, fertilizers, etc.; potentially running off into Buskin Lake, the source of drinking water (see H above).

Q Barrel dump (below the road); no known history/volume/ contents.

R Active Coast Guard landfill; previously documented problems with leaching and runoff. Upgraded over last few years: (1) dike around border to prevent runoff from flowing through landfill and into Lake Louise and Buskin River; (2) emplaced an underground drain system to collect leachate which is piped to sewage treatment plant for disposal (since 7/1/86).

S Abandoned Navy landfill that may be responsible for discoloration of lake/pool there; may leach into Buskin River.

T Site of chronic fuel leakage (JP-5) from deteriorated underground pipes. 50,000 gallons recovered; unknown quantities seeped into adjacent marine system.

U Site of ammunition storage (and unknown additional military materials); adjacent to Devils Creek which empties into Buskin River. No details available.

Table 2. Analytes for the Womens Bay Contaminant Study.

INORGANICS

antimony (Sb)
arsenic (As)
cadmium (Cd)
chromium (Cr)
copper (Cu)
iron (Fe)
manganese (Mn)
mercury (Hg)
nickel (Ni)
lead (Pb)
selenium (Se)
thallium (Tl)

POLYNUCLEAR AROMATIC HYDROCARBONS

naphthalene
1-methylnaphthalene
2-methylnaphthalene
2,6 dimethylnaphthalene
2,3,4-trimethylnaphthalene
1-methylphenanthrene
acenaphthylene
acenaphthene
fluorene
phenanthrene
anthracene
fluoranthene
pyrene
benzo(a)anthracene
chrysene
benzo(b)fluoranthene
benzo(k)fluoranthene
benzo(e)pyrene
benzo(a)pyrene
perylene
indeno(1,2,3-c,d)pyrene
dibenzo(a,h)anthracene
benzo(g,h,i)perylene
biphenyl

ORGANOCHLORINES

oxychlordane
cis-nonachlor
alpha chlordane
gamma chlordane
transnonachlor
heptachlor
heptachlorepoxide
o,p'-DDE
p,p'-DDE
o,p'-DDD
p,p'-DDD
o,p'-DDT
p,p'-DDT
total DDT
mirex
dieldrin
aldrin
alpha BHC
hexachlorobenzene
beta BHC
lindane
delta BHC
total Cl-2 (PCB)
total Cl-3 (PCB)
total Cl-4 (PCB)
total Cl-5 (PCB)
total Cl-6 (PCB)
total Cl-7 (PCB)
total Cl-8 (PCB)
total Cl-9 (PCB)
total PCBs
toxaphene

Table 3. PAH analytes from Womens Bay samples exceeding 0.10 ppm (>ten times the detection limit).

POLYNUCLEAR AROMATIC HYDROCARBONS	SAMPLE NUMBER												
	6B	7B	8B	9B	38B	39B	40B	41B	42B	43B	44B	45B	46B
naphthalene													
1-methylnaphthalene													
2-methylnaphthalene													
2,6 dimethylnaphthalene													
2,3,4-trimethylnaphthalene													
1-methylphenanthrene										+			
acenaphthylene													
acenaphthene										+			
fluorene			+							+			
phenanthrene	+	+	+	+	+		+						
anthracene					+					+			
fluoranthene					+	+	+	+	+	+	+	+	+
pyrene					+	+	+	+	+	+	+	+	+
benzo(a)anthracene					+			+	+	+			
chrysene					+		+	+	+	+	+	+	
benzo(b)fluoranthene					+			+	+	+	+		
benzo(k)fluoranthene								+	+	+			
benzo(e)pyrene								+	+	+			
benzo(a)pyrene					+			+	+	+			
perylene										+			
indeno(1,2,3-c,d)pyrene								+	+	+			
dibenzo(a,h)anthracene										+			
benzo(g,h,i)perylene								+	+	+			
biphenyl													

Figure 1. General location of Alaska Maritime National Wildlife Refuge.

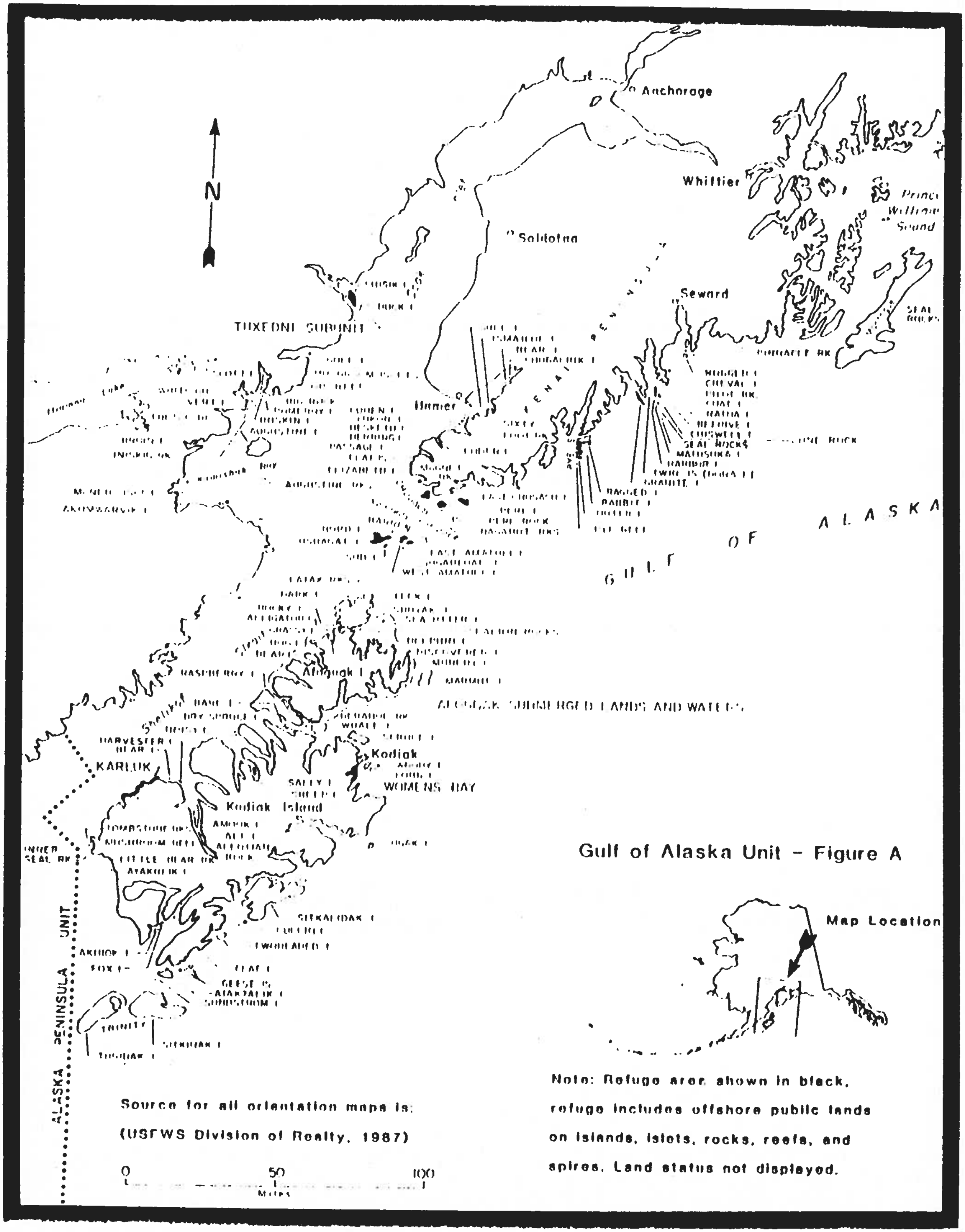

Figure 2. Location of Womens Bay Subunit of Alaska Maritime National Wildlife Refuge.

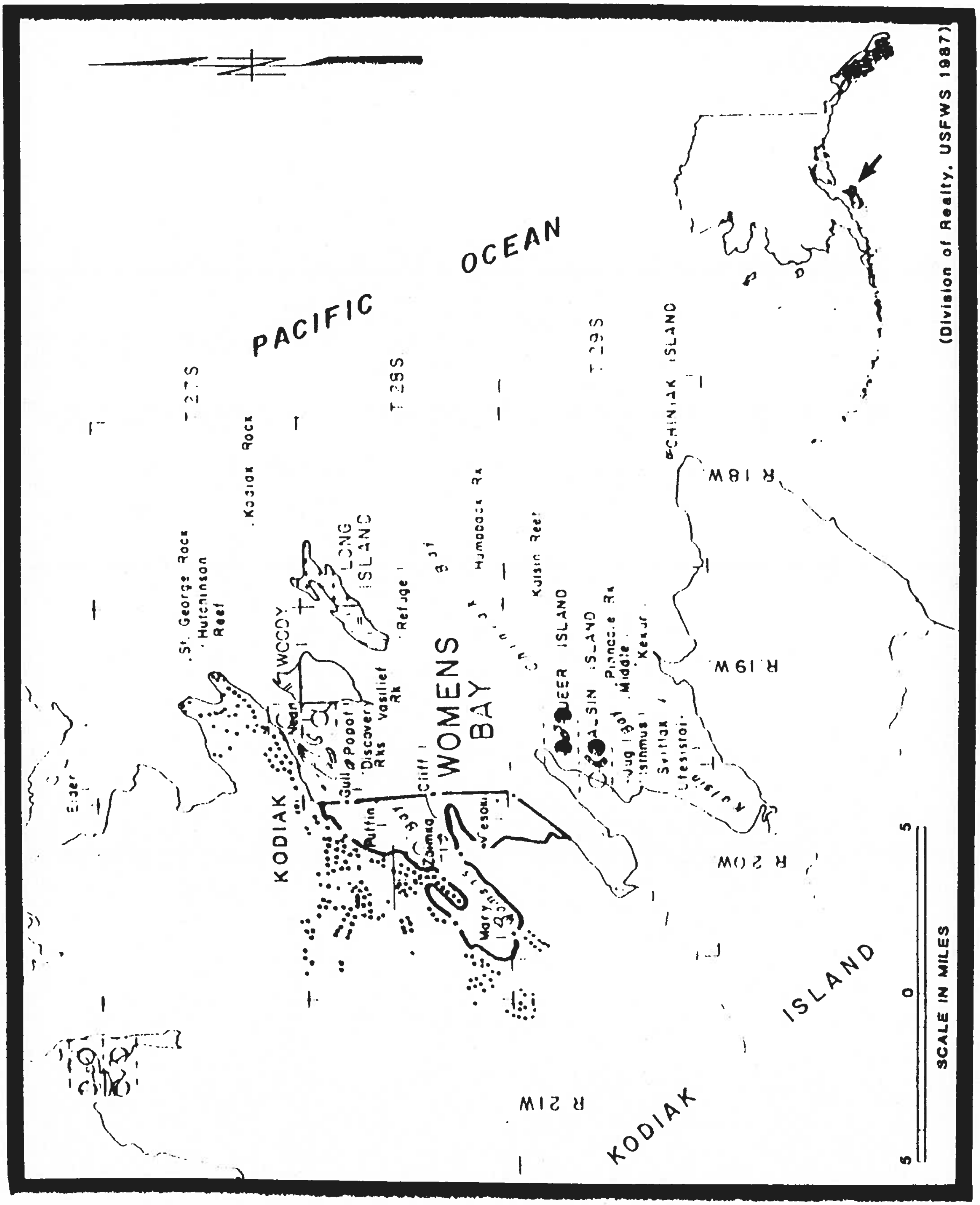

Figure 3. Location of potential contaminant sources in and near Womens Bay, Alaska.

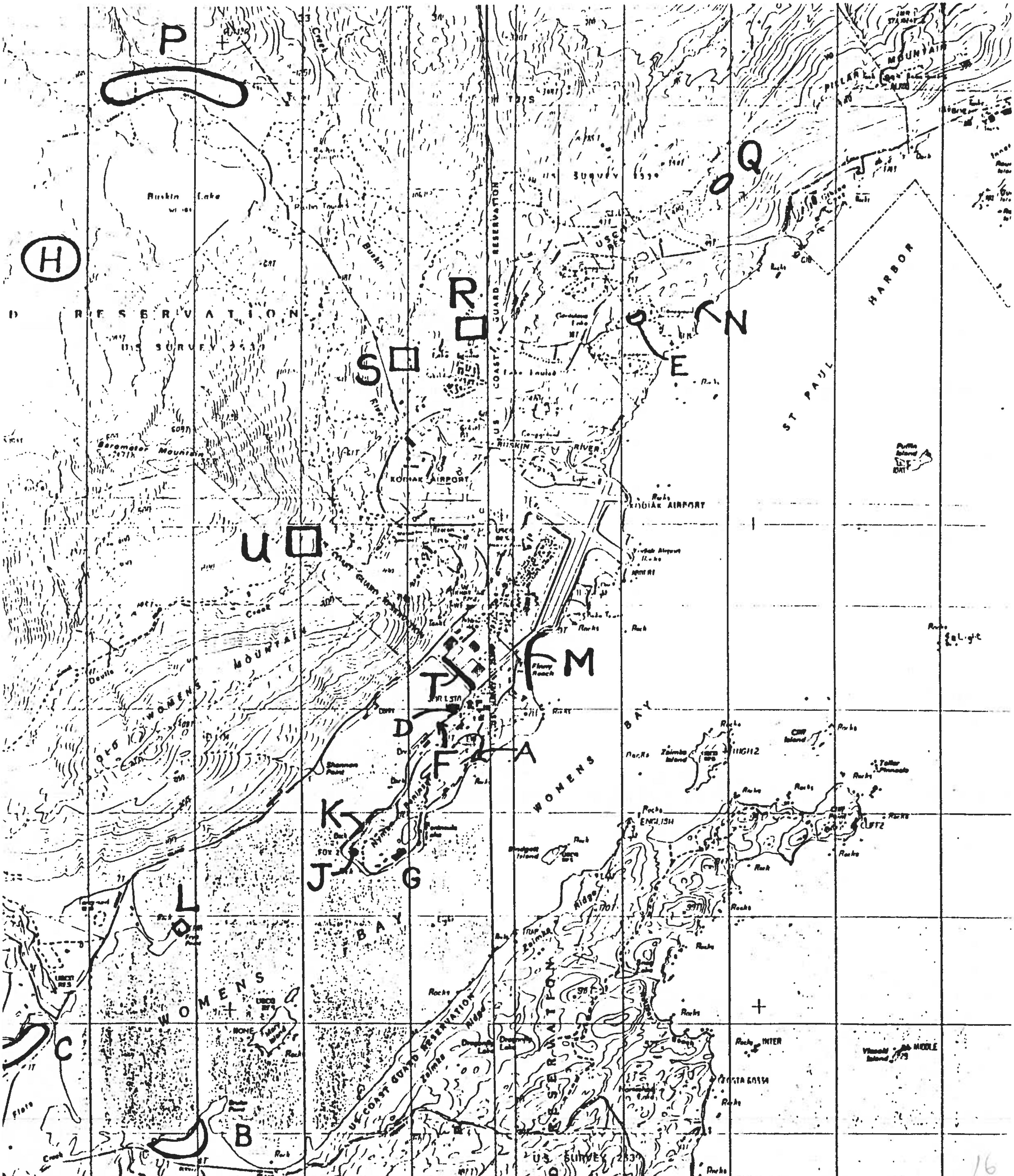

Figure 4. Specific study sample sites and zones.

Appendix A. Samples taken for metal analyses - Alaska Maritime National Wildlife Refuge (Womens Bay)

Sample Number	Zone	Sample ID	Tissue or Matrix	Sample Type	Collection Site Description	Collection Date	Analysis Requested and Remarks
1	1	WB-BR-1-M	Sediment	I	Buskin River Mouth-offshore	08/25/87	HM; 7 feet deep
2	1	WB-BR-2-M	Sediment	I	Buskin River Mouth-offshore	08/25/87	HM; 6 feet deep
3	1	WB-BR-3-M	Sediment	I	Buskin River Mouth-offshore	08/25/87	HM; 7 feet deep
4	1	WB-BR-4-M	Sediment	I	Buskin River Mouth-200m upstream	08/31/87	HM; mudflats
5	1	WB-BR-5-M	Sediment	I	Buskin River Mouth-200m upstream	08/31/87	HM; mudflats
6	1	WB-BR-6-M	Sediment	I	Buskin River Mouth-1/4 mi. upstr.	08/31/87	HM; mudflats
7	1	WB-BR-7-M	Sediment	I	Buskin River Mouth-1/4 mi. upstr.	08/31/87	HM; mudflats
8	1	WB-BR-8-M	Sediment	I	Buskin River Mouth-1/4 mi. upstr.	08/31/87	HM; mudflats
9	1	WB-BR-9-M	Sediment	I	Buskin River Mouth-1/4 mi. upstr.	08/31/87	HM; mudflats
10	1	WB-BR-11-M	crabs (4)	C	Buskin River Mouth-offshore	08/31/87	HM; 15' deep; hermits
11	1	WB-BR-12-M	Snails (10)	C	Buskin River Mouth-offshore	08/31/87	HM; 15 feet deep
12	1	WB-BR-14-M	cockle	I	Buskin River Mouth-sandy beach	08/31/87	HM; 8 feet deep
13	1	WB-BR-15-M	crabs (2)	C	Buskin River Mouth-sandy beach	08/31/87	HM; 8' deep; dungeness
14	2	WB-SMF-1-M	clams (3)	C	S. mudflats	08/26/87	HM
15	2	WB-SMF-2-M	clams (2)	C	S. mudflats	08/26/87	HM
16	2	WB-SMF-3-M	clams (2)	C	S. mudflats	08/26/87	HM
17	2	WB-SMF-4-M	clams (2)	C	S. mudflats	08/26/87	HM
18	2	WB-SMF-5-M	clams (2)	C	S. mudflats	08/26/87	HM
19	2	WB-SMF-6-M	clams (2)	C	S. mudflats	08/26/87	HM
20	2	WB-SMF-7-M	Mussels (8)	C	S. mudflats	08/26/87	HM
21	3	WB-SMF-8-M	Sediment	I	S. mudflats	08/26/87	HM; 19 feet deep
22	3	WB-SMF-9-M	Sediment	I	S. mudflats	08/26/87	HM; 25 feet deep
23	3	WB-SMF-10-M	Sediment	I	S. mudflats	08/26/87	HM; 23 feet deep
24	3	WB-SMF-11-M	Sediment	I	S. mudflats	08/26/87	HM; 48 feet deep
25	3	WB-SMF-12-M	Sediment	I	S. mudflats	08/26/87	HM; 41 feet deep
26	3	WB-SMF-13-M	Sediment	I	S. mudflats	08/26/87	HM; 22 feet deep
27	3	WB-SMF-14-M	Sediment	I	S. mudflats	08/26/87	HM; 18 feet deep
28	3	WB-SMF-15-M	Sediment	I	S. mudflats	08/26/87	HM; 19 feet deep
29	3	WB-SMF-16-M	Sediment	I	S. mudflats	08/26/87	HM; 27 feet deep

C = composite
I = individual
HM = heavy metals (Sb, As, Cd, Cr, Cu, Fe, Pb, Hg, Mn, Ni, Se)

18

Appendix A (cont.). Samples taken for metal analyses - Alaska Maritime National Wildlife Refuge (Womens Bay)

Sample Number	Zone	Sample ID	Tissue or Matrix	Sample Type	Collection Site Description	Collection Date	Analysis Requested and Remarks
30	3	WB-SMF-17-M	Sediment	I	S. mudflats	08/25/87	HM; 45 feet deep
31	3	WB-SMF-18-M	Sediment	I	S. mudflats	08/25/87	HM; 31 feet deep
32	3	WB-SMF-19-M	Sediment	I	S. mudflats	08/25/87	HM; 19 feet deep
33	3	WB-SMF-20-M	Sediment	I	S. mudflats	08/31/87	HM; 21 feet deep
34	2	WB-SMF-21-M	clams (5)	C	S. mudflats	08/31/87	HM
35	2	WB-SMF-22-M	clams (9)	C	S. mudflats	08/31/87	HM
36	2	WB-SMF-23-M	mussels (11)	C	S. mudflats	08/31/87	HM
37	3	WB-SMF-24-M	crab (3)	C	S. mudflats	08/31/87	HM; 25 feet deep
38	4	WB-NP-1-M	Sed/Veg mix	I	Nyman Penn.-storage area	08/31/87	HM; 8 feet deep
39	4	WB-NP-2-M	Sed/Veg mix	I	Nyman Penn.-storage area	08/31/87	HM; 6 feet deep
40	4	WB-NP-3-M	Sed/Veg mix	I	Nyman Penn.-storage area	08/31/87	HM; 8 feet deep
41	5	WB-NP-4-M	Sediment	I	Nyman Penn.-Lash area	08/31/87	HM; 38 feet deep
42	5	WB-NP-5-M	Sediment	I	Nyman Penn.-NW corner of gut	08/26/87	HM; 23 feet deep
43	5	WB-NP-6-M	Sed/Veg mix	I	Nyman Penn.-near boom	08/26/87	HM; 6 feet deep
44	5	WB-NP-7-M	Sediment	I	Nyman Penn.-N end of dock	08/26/87	HM; 30 feet deep
45	5	WB-NP-8-M	Sediment	I	Nyman Penn.-N end of marginal	08/26/87	HM; 52 feet deep
46	5	WB-NP-9-M	Sediment	I	Nyman Penn.-S end of marginal	08/26/87	HM; 50 feet deep
47	6	WB-NP-10-M	mussels (13)	C	Nyman Penn.-outside boom	08/26/87	HM; side closest to ramp
48	6	WB-NP-11-M	mussels (10)	C	Nyman Penn.-between boom	08/26/87	HM; near concrete outfall
49	6	WB-NP-12-M	mussels (14)	C	Nyman Penn.-between boom	08/26/87	HM; far side of mid ramp
50	6	WB-NP-13-M	mussels (12)	C	Nyman Penn.-near eelgrass	08/26/87	HM; between ramps 2 & 3
51	5	WB-NP-14-M	crab (4)	C	Nyman Penn.-NW corner of gut	08/26/87	HM; 25 feet deep; tanner
52	5	WB-NP-15-M	crab (2)	C	Nyman Penn.-N end of marginal	08/26/87	HM; 35 feet deep; tanner
53	4	WB-NP-16-M	crab (2)	C	Nyman Penn.-storage area	08/26/87	HM; 8 feet deep; hairy
54	7	WB-NP-17-M	crab (2)	C	Nyman Penn.-SE side of Zaimka	08/26/87	HM; 10 feet deep; hairy
55	5	WB-NP-18-M	crab (1)	I	Nyman Penn.-near eelgrass	08/26/87	HM; 15 feet deep; hairy
56	1	WB-BR-10	fish	I	Buskin River Mouth	08/26/87	HM; flounder
57	1	WB-BR-11	crab	I	Buskin River Mouth -15 feet deep	08/26/87	HM; hairly crab

C = composite
I = individual
HM = heavy metals (Sb, As, Cd, Cr, Cu, Fe, Pb, Hg, Mn, Ni, Se)

Appendix B. Samples taken for organic analyses - Alaska Maritime National Wildlife Refuge (Womens Bay)

Sample Number	Zone	Sample ID	Tissue or Matrix	Sample Type	Collection Site Description	Collection Date	Analysis Requested and Remarks
1B	1	WB-BR-1-0	Sediment	I	Buskin River Mouth-offshore	08/28/87	O,H; 7 feet deep
2B	1	WB-BR-2-0	Sediment	I	Buskin River Mouth-offshore	08/25/87	O,H; 6 feet deep
3B	1	WB-BR-3-0	Sediment	I	Buskin River Mouth-offshore	08/25/87	O,H; 7 feet deep
4B	1	WB-BR-4-0	Sediment	I	Buskin River Mouth-200m upstream	08/31/87	O,H; mudflats
5B	1	WB-BR-5-0	Sediment	I	Buskin River Mouth-200m upstream	08/31/87	O,H mudflats
6B	1	WB-BR-6-0	Sediment	I	Buskin River Mouth-1/4mi. upstr.	08/31/87	O,H mudflats
7B	1	WB-BR-7-0	Sediment	I	Buskin River Mouth-1/4mi. upstr.	08/31/87	O,H mudflats
8B	1	WB-BR-8-0	Sediment	I	Buskin River Mouth-1/4mi. upstr.	08/31/87	O,H; mudflats
9B	1	WB-BR-9-0	Sediment	I	Buskin River Mouth-1/4mi. upstr.	08/31/87	O,H; mudflats
10B	1	WB-BR-11-0	crabs (5)	C	Buskin River Mouth-offshore	08/31/87	O,H; 15' deep; hairy
11B	1	WB-BR-13-0	snails (10)	C	Buskin River Mouth-offshore	08/31/87	O,H; 15 feet deep
12B	1	WB-BR-14-0	cockle	I	Buskin River Mouth-sandy beach	08/31/87	O,H; 8 feet deep
13B	1	WB-BR-15-0	clams (2)	C	Buskin River Mouth-sandy beach	08/31/87	O,H; 8' deep; dungeness
14B	2	WB-SMF-1-0	clams (3)	C	S. mudflats	08/26/87	O,H
15B	2	WB-SMF-2-0	clams (2)	C	S. mudflats	08/26/87	O,H
16B	2	WB-SMF-3-0	clams (2)	C	S. mudflats	08/26/87	O,H
17B	2	WB-SMF-4-0	clams (2)	C	S. mudflats	08/26/87	O,H
18B	2	WB-SMF-5-0	clams (2)	C	S. mudflats	08/26/87	O,H
19B	2	WB-SMF-6-0	clams (2)	C	S. mudflats	08/26/87	O,H
20B	2	WB-SMF-7-0	mussels (8)	C	S. mudflats	08/26/87	O,H
21B	3	WB-SMF-8-0	Sediment	I	S. mudflats	08/26/87	O,H; 19 feet deep
22B	3	WB-SMF-9-0	Sediment	I	S. mudflats	08/29/87	O,H; 25 feet deep
23B	3	WB-SMF-10-0	Sediment	I	S. mudflats	08/26/87	O,H; 23 feet deep
24B	3	WB-SMF-11-0	Sediment	I	S. mudflats	08/26/87	O,H; 48 feet deep
25B	3	WB-SMF-12-0	Sediment	I	S. mudflats	08/26/87	O,H; 41 feet deep
26B	3	WB-SMF-13-0	Sediment	I	S. mudflats	08/26/87	O,H; 22 feet deep
27B	3	WB-SMF-14-0	Sediment	I	S. mudflats	08/26/87	O,H; 18 feet deep
28B	3	WB-SMF-15-0	Sediment	I	S. mudflats	08/26/87	O,H; 19 feet deep
29B	3	WB-SMF-16-0	Sediment	I	S. mudflats	08/25/87	O,H; 27 feet deep

C = composite
I = individual
O = organochlorines including PCBs
H = aliphatic and aromatic hydrocarbons (HC Scans I and II)

20

Appendix B (cont.). Samples taken for organic analyses - Alaska Maritime National Wildlife Refuge (Womens Bay)

Sample Number	Zone	Sample ID	Tissue or Matrix	Sample Type	Collection Site Description	Collection Date	Analysis Requested and Remarks
30B	3	WB-SMF-17-0	Sediment	I	S. mudflats	08/28/87	O,H; 45 feet deep
31B	3	WB-SMF-18-0	Sediment	I	S. mudflats	08/28/87	O,H; 31 feet deep
32B	3	WB-SMF-19-0	Sediment	I	S. mudflats	08/28/87	O,H; 19 feet deep
33B	3	WB-SMF-20-0	Sediment	I	S. mudflats	08/28/87	O,H; 21 feet deep
34B	3	WB-SMF-21-0	Sediment	I	S. mudflats	08/27/87	O,H
35B	2	WB-SMF-22-0	Sediment	I	S. mudflats	08/27/87	O,H
36B	2	WB-SMF-23-0	Sediment	I	S. mudflats	08/27/87	O,H
37B	3	WB-SMF-24-0	Sediment	I	S. mudflats	08/29/87	O,H; 25 feet deep; dungeness
38B	4	WB-NP-1-0	Sed/Veg mix	I	Nyman Penn.-storage area	08/26/87	O,H; 8 feet deep
39B	4	WB-NP-2-0	Sed/Veg mix	I	Nyman Penn.-storage area	08/26/87	O,H; 6 feet deep
40B	4	WB-NP-3-0	Sed/Veg mix	I	Nyman Penn.-storage area	08/26/87	O,H; 8 feet deep
41B	5	WB-NP-4-0	Sediment	I	Nyman Penn.-lash area	08/28/87	O,H; 38 feet deep
42B	5	WB-NP-5-0	Sediment	I	Nyman Penn.-NW corner of gut	08/28/87	O,H; 23 feet deep
43B	5	WB-NP-6-0	Sed/Veg mix	I	Nyman Penn.-near boom	08/28/87	O,H; 6 feet deep
44B	5	WB-NP-7-0	Sediment	I	Nyman Penn.-N end of dock	08/28/87	O,H; 30 feet deep
45B	5	WB-NP-8-0	Sediment	I	Nyman Penn.-N end of marginal	08/28/87	O,H; 52 feet deep
46B	5	WB-NP-9-0	Sediment	I	Nyman Penn.-S end of marginal	08/28/87	O,H; 50 feet deep
47B	6	WB-NP-10-0	mussels (13)	C	Nyman Penn.-outside boom	08/28/87	O,H; side closest to ramp
48B	6	WB-NP-11-0	mussels (9)	C	Nyman Penn.-between booms	08/28/87	O,H; near outfall
49B	6	WB-NP-12-0	mussels (14)	C	Nyman Penn.-between booms	08/28/87	O,H; far side of mid ramp
50B	6	WB-NP-13-0	mussels (12)	C	Nyman Penn.-near eelgrass	08/28/87	O,H; between ramps 2 & 3
51B	5	WB-NP-14-0	crabs (4)	C	Nyman Penn.-NW corner of gut	08/29/87	O,H; 25 feet deep; tanner
52B	5	WB-NP-15-0	crab	I	Nyman Penn.-N end of marginal	08/29/87	O,H; 35 feet deep; tanner
53B	4	WB-NP-16-0	crab	I	Nyman Penn.-storage area	08/29/87	O,H; 8 feet deep; hairy
54B	7	WB-NP-17-0	crabs (2)	C	Nyman Penn.-SE side of Zaimka	08/29/87	O,H; 10 feet deep; hairy
55B	5	WB-NP-18-0	crab	I	Nyman Penn.-near eelgrass	08/29/87	O,H; 15 feet deep; hairy
56B	1	WB-BR-10	Fish	I	Buskin River Mouth	08/31/87	O,H; flounder
57B	1	WB-BR-12	crab	I	Buskin River Mouth - 15 feet deep	08/31/87	O,H; hairy crab

C = composite
I = individual
O = organochlorines <u>including PCBs</u>
H = aliphatic and aromatic hydrocarbons (HC Scans I and II)

Appendix C. Trace metal concentrations (ppm; dw) in Womens Bay samples - BIOTA

Organism (No.)	Zone	Sample No.	Sb	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se
Flounder (1)	1	56	ND	1.1	ND	3.0	13.8	126.	.29	17.2	ND	4.0	.95
Dungeness crab (2)	1	13	ND	23.8	.32	1.5	37.3	356.	2.2	10.6	ND	2.6	1.4
Hairy crab (1)	1	57	ND	9.0	.58	1.9	35.4	84.	.79	6.9	ND	1.9	ND
Hairy crab (3)	3	37	ND	11.0	.32	2.3	37.2	623.	.76	124.	ND	1.5	.7
Hairy crab (2)	4	53	ND	11.0	.44	1.4	29.7	466.	.81	86.2	ND	.8	.8
Hairy crab (2)	7	54	ND	14.0	2.0	1.2	46.2	231.	.85	16.1	ND	1.8	.6
Hairy crab (1)	5	55	ND	7.6	.23	2.3	57.1	887.	1.8	36.8	ND	2.0	.6
Tanner crab (4)	5	51	ND	16.0	.28	1.2	62.2	629.	2.7	27.1	ND	1.4	.9
Tanner crab (2)	5	52	ND	28.4	.86	1.6	86.8	360.	.33	8.3	ND	1.4	1.4
Hermit crab (4)	1	10	ND	16.0	.34	1.0	69.4	141.	ND	5.4	ND	.9	ND
clams (3)	2	14	ND	7.6	1.0	2.9	16.5	2060.	1.0	165.	ND	2.9	1.6
clams (2)	2	15	ND	11.0	.44	7.0	12.1	4430.	1.2	94.4	ND	3.7	1.4
clams (2)	2	16	ND	7.1	.60	3.8	10.2	2040.	.82	158.	ND	2.9	1.2
clams (2)	2	17	ND	11.0	.75	4.7	20.4	3320.	1.3	125.	ND	4.3	1.6
clams (2)	2	18	ND	8.3	.43	1.7	24.1	1310.	.82	128.	ND	4.1	1.3
clams (2)	2	19	ND	14.0	.43	4.7	26.9	3440.	1.7	193.	ND	4.8	1.5
clams (5)	2	34	ND	7.8	.34	4.5	15.5	3400.	1.2	132.	ND	4.3	1.3
clams (9)	2	35	ND	8.3	.51	2.8	15.9	3360.	1.3	147.	ND	4.4	1.6
cockle (1)	1	12	ND	2.6	.39	3.0	6.3	1360.	3.6	10.0	ND	11.9	2.7
Snail (10)	1	11	ND	15.0	21.2	1.4	17.0	69.	.24	9.8	ND	.67	1.0
mussel (8)	2	20	ND	16.0	1.9	1.9	7.7	609.	.83	20.1	ND	2.4	1.8
mussel (11)	2	36	ND	14.0	1.5	1.4	7.0	452.	.59	14.9	ND	2.9	1.7
mussel (13)	6	47	ND	12.0	2.2	3.3	9.3	1140.	2.6	47.3	.13	1.9	2.0
mussel (10)	6	48	ND	11.0	1.8	1.2	7.0	233.	1.5	28.0	ND	1.2	1.4
mussel (14)	6	49	ND	8.2	2.3	2.6	8.1	232.	1.0	79.2	ND	2.2	1.9
mussel (12)	6	50	ND	12.0	2.2	2.0	8.0	895.	6.9	57.7	.10	2.1	1.8
eelgrass	4	38	ND	19.0	.66	6.9	20.6	17700.	55.2	151.	ND	9.9	ND
eelgrass	4	39	ND	8.1	.44	5.5	15.0	13300.	34.2	81.7	ND	10.6	ND
eelgrass	4	40	ND	1.4	1.1	5.7	11.2	11500.	18.8	342.	ND	7.7	ND
eelgrass	5	43	ND	ND	.39	15.0	74.7	17300.	20.6	293.	ND	24.7	ND

Appendix C.(cont.) Trace metal concentrations (ppm; dw) in Womens Bay samples - SEDIMENT

Zone	Sample No.	Sb	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se
1	1	ND	7.0	ND	12.3	7.4	12500.	3.7	182.	ND	9.9	ND
1	2	0.85	6.7	ND	16.7	8.1	16600.	2.8	236.	ND	14.0	ND
1	3	ND	5.6	ND	13.0	8.5	13500.	4.9	195.	ND	11.3	ND
1	4	ND	8.4	ND	23.8	20.8	23400.	8.8	341.	ND	20.3	ND
1	5	ND	10.0	ND	22.8	19.1	22600.	8.0	309.	ND	19.2	ND
1	6	3.1	18.8	ND	20.8	29.2	24100.	11.0	332.	ND	22.6	ND
1	7	ND	15.0	.15	19.6	34.2	23800.	15.1	284.	ND	21.8	2.3
1	8	.63	20.1	.10	18.4	30.8	21300.	12.2	264.	ND	20.6	ND
1	9	ND	21.0	ND	18.9	27.5	21400.	11.4	344.	ND	19.2	.68
3	21	ND	15.0	ND	9.7	17.8	10400.	7.8	133.	ND	10.0	ND
3	22	.72	16.0	.13	15.7	31.6	16700.	11.4	213.	.15	16.1	ND
3	23	ND	18.7	.15	18.1	36.0	19300.	12.0	252.	.15	18.6	ND
3	24	ND	13.0	.15	24.8	50.9	26500.	17.1	339.	.20	26.7	ND
3	25	2.0	13.0	.13	20.6	41.1	21800.	14.5	283.	.16	22.2	ND
3	26	ND	11.0	ND	19.0	34.9	20400.	12.0	259.	.16	19.9	ND
3	27	ND	20.4	ND	23.6	48.4	26500.	14.9	342.	.18	27.2	ND
3	28	ND	16.0	ND	23.0	42.6	24500.	12.8	318.	.18	25.6	ND
3	29	ND	14.0	.11	25.1	53.2	27100.	17.1	348.	.13	28.3	ND
3	30	ND	11.0	.12	25.4	52.6	26900.	17.5	346.	.13	27.4	ND
3	31	ND	24.9	.12	22.3	48.2	24000.	15.5	306.	.11	25.1	ND
3	32	ND	15.0	.12	22.7	46.3	24300.	13.0	323.	.10	25.2	.60
3	33	ND	17.5	ND	21.3	43.6	24800.	12.8	313.	.16	23.4	ND
4	38	ND	12.0	.11	17.7	23.2	20600.	31.2	309.	ND	16.2	ND
4	39	ND	8.4	.12	19.2	25.8	22600.	48.8	279.	ND	17.2	ND
4	40	ND	9.1	.12	17.2	17.7	18700.	17.8	270.	ND	14.2	ND
4	41	ND	14.0	.13	22.2	57.9	23700.	25.9	297.	.21	25.5	ND
4	42	ND	16.0	.16	27.2	77.8	27700.	30.0	366.	.27	32.8	ND
4	43	ND	33.3	ND	25.3	82.6	34500.	20.8	506.	.16	36.2	ND
4	44	ND	24.5	.14	23.1	92.7	28300.	32.0	403.	.21	33.0	ND
4	45	ND	9.1	.15	21.0	45.0	24300.	20.6	295.	.18	21.2	ND
4	46	ND	8.8	.16	19.3	38.3	20900.	17.1	253.	.13	18.7	ND

Appendix D: Profiles of contaminant-categories and contaminants of concern.

POLYCYCLIC AROMATIC HYDROCARBONS

Polycyclic aromatic hydrocarbons (PAHs) are a widely-distributed group of environmental contaminants, many of which are known to be mutagenic and some carcinogenic. Besides being produced by anthropogenic sources (i.e., petroleum products, combustion of fossil fuels), PAHs are also synthesized by microorganisms, algae, and macrophytes.

Concern about PAHs in the environment is due to their persistence and to the fact that some are known to be potent mammalian carcinogens. PAHs can be taken into the mammalian body by inhalation, skin contact, or ingestion. In water, PAHs may either evaporate, disperse into the water column, concentrate in aquatic biota (aquatic invertebrates), experience chemical oxidation and biodegradation, or become incorporated into bottom sediments. The ultimate fate of those PAHs that accumulate in sediments is believed to be biotransformation and biodegradation by benthic organisms (EPA 1980). Fish do not appear to contain grossly elevated PAH residues; this may be related to their efficient PAH degradation system. PAHs in the soil may be assimilated by plants before entering the food chain, degraded by soil microorganisms, or accumulate to relatively high levels in the soil. There is very little information on contemporary normal (or typical) levels of PAHs in soils (Jones et al. 1989). However, Edwards (1983) states that typical endogenous concentrations of PAHs in soil range from 0.001 to 0.01 ppm.

In view of the carcinogenic characteristics of many PAH compounds and their increasing concentrations in the environment, it appears prudent to reduce or eliminate them wherever possible, pending acquisition of more definitive ecotoxicological data.

naphthalene-based compounds (naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, 2,6-dimethylnaphthalene, 2,3,4-trimethylnaphthalene): naphthalene is used as an intermediate in the production of dye compounds and the formulation of solvents, lubricants, and motor fuels. Naphthalene vapor and dust can form explosive mixtures with air. Poisoning can occur by ingestion, inhalation or skin absorption. Acute and chronic toxicity to freshwater aquatic life (fish) occur at concentrations as low as 2.3 ppm and .620 ppm, respectively, and possibly at lower concentrations. It is not carcinogenic. Naphthalene is probably the most easily biodegraded PAH.

biphenyl: powerful, irritating poison by inhalation. Moderately toxic by ingestion. Found in coal tar, wood preservatives and petroleum products. An experimental tumorigen and carcinogen.

Appendix D: Continued Profiles of contaminants of concern.

1-methylphenanthrene: found in wood preservative sludge, crude oil, gasoline (3.18 ppm) and in exhaust condensate of gasoline engines.

acenaphthylene: in soots generated by the combustion of aromatic hydrocarbon fuel doped with pyridine. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it quite persistent and may accumulate to high concentrations. It can be absorbed from ingestion, inhalation and skin contact. The present data base is inadequate to support the derivation of drinking water criteria for this compound.

acenaphthene: product of petroleum refining, shale oil processing, coal tar distilling. Used in plastics mfg; insecticide and fungicide mfg. Constituent in asphalt and in soots generated by combustion of aromatic fuels. Known to be mutagenic. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it is quite persistent and may accumulate to high concentrations. It is not very water soluble. Resists photochemical degradation in soil. Its ultimate fate in the aquatic system is accumulation in sediment and biodegraded and biotransformed by benthic organisms. Levels on the order of 0.5 to 2 ppm are acutely toxic to aquatic animals and algae. Levels above 0.7 ppm may present a chronic toxicity hazard to fish.

fluorene: Little information exists about the fate of fluorene in the aquatic environment; its aquatic fate, therefore, if inferred for the most part from data summarized for polycyclic aromatic hydrocarbons.

fluorene (continued): Fluorene's aquatic solubility is 1.9 mg/l and it is strongly sorbed onto suspended particulates and in biota. It is not known to be carcinogenic. No data about the bioaccumulation of fluorene were available. Biodegradation and biotransformation may be the dominant fate process in the aquatic environment for fluorene. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it is quite persistent and may accumulate to high concentrations.

phenanthrene: used in dyestuffs, explosives, synthesis of drugs. Found in crude oil, gasoline at 15.7 mg/l, and in exhaust condensate of gasoline engines. Not carcinogenic. Moderately toxic by ingestion. When found in sediments it is less subject to photochemical or biological oxidation; therefore, it is quite persistent and may accumulate to high concentrations. It is not very water soluble. No acute hazard levels identified or recommended for drinking water.

Appendix D: Continued Profiles of contaminants of concern.

anthracene: A skin irritant, allergen, and experimental carcinogen. Known to be a mutagen. Combustible when exposed to heat or flames. Found in gasoline at 1.55 mg/l, in exhaust condensate of gasoline engine (0.53 - 0.64 mg/l). No effect on trout exposed to 5 mg/l anthracene, for 24 hours. Sorbed onto suspended particles and inorganic sediment and in biota. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms. Food chain magnification of this chemical is not likely to be significant due to the rapid direct uptake of anthracene from water by fish.

fluoranthene: found in crude oil, wood preservative sludge, gasoline, lubricating motor oils, motor oils and exhaust condensate from gasoline engines (1.06 - 1.66 mg/l). Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms. Moderately toxic by ingestion and skin contact. An experimental tumorigen. Photochemical oxidation appears to be an important process in the destruction of oil slicks which contain fluoranthene.

pyrene: found in gasoline, crude oil, motor oil, exhaust condensate of gasoline engines and is emitted from hot asphalt. Carcinogenic to man. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain.

benzo(a)anthracene: found in gasoline (0.232 mg/l), crude oil, exhaust condensate of gasoline engines (0.5 -0.08 mg/l) and wood preservative sludge. It is carcinogenic and mutagenic. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain. Crustaceans are most sensitive and fish are more resistant.

chrysene: found in gasoline (0.052 mg/l - 2.96 mg/l), motor oil, crude oil, and tail gases and condensate of gasoline engines. A weak carcinogen and mutagen. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain. Crustaceans are most sensitive and fish are more resistant. No recommended drinking water limit has been established, as the available data base in inadequate.

Appendix D: Continued Profiles of contaminants of concern.

benzo(b)fluoranthene: found in crude oil, gasoline (0.16 - 1.34 mg/l), motor oil and in tail gases and exhaust condensate of gasoline engines. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain. Not carcinogenic.

benzo(k)fluoranthene: found in crude oil, gasoline (.009 mg/l), and in tail gases and exhaust condensate of gasoline engines. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain.

benzo(a)pyrene: a poison via subcutaneous route. An experimental carcinogen. Manufactured sources include petroleum refining, kerosene processing and heat and power generating sources. Man caused sources include combustion of fuels, present in run off containing greases, oils, etc.; potential road bed and asphalt leachate. In gasoline (0.135 mg/l - 0.143 mg/l); fresh motor oil (0.02 mg/l - 0.10 mg/l); used motor oil (5.8 mg/l - 242.4 mg/l). Found in exhaust condensate of gasoline engines. A known strong carcinogen and mutagen.

benzo(a)pyrene (continued): Less bioavailable when complexed to colloidal organic materials or adsorbed to organic or inorganic particulates than when in solution or in fine dispersion in water. Usually filter-feeding bivalve mollusks contain lower concentrations than the algae and plankton they feed upon. Demersel fish species do not contain notably higher concentrations than do pelagic species.

benzo(e)pyrene: found in gasoline (0.18 mg/l -1.82 mg/l), lubricating motor oils (0.07 - 0.49 mg/l), used motor oil (92.2 mg/l - 278.4 mg/l) and crude oil. Known to be a weak experimental carcinogen.

perylene: **Manmade** sources include crude oil, gasoline (0.018 mg/l - 0.16 mg/l), lubricating motor oils (0.01 mg/l - 0.09 mg/l), fresh motor oil (0.03 mg/l), used motor oil (14.3 mg/kg - 57.4 mg/kg).

indeno-(1,2,3-c,d)pyrene: No commercial uses. Manmade sources include gasoline (0.059 mg/l), fresh motor oil (0.03 mg/kg), and used motor oil (34.0 mg/kg to 83.3 mg/kg). Found in tail gases and exhaust condensate of gasoline engines. Less subject to photochemical or biological oxidation, especially if the sediment is anoxic. Therefore, it is quite persistent and may accumulate to high concentrations. An experimental carcinogen. Can be absorbed from inhalation, ingestion and skin contact. In most cases, crustaceans are more sensitive than fish.

dibenzo(a,h)anthracene: poison by intravenous route. An experimental carcinogen. When heated to decomposition it emits acrid smoke and irritating fumes.

benzo(g,h,i)perylene: Manmade sources include fresh motor oil (0.12 mg/kg), used motor oil (108.8 mg/kg - 289.4 mg/kg), crude oil and gasoline (0.32 mg/kg - 1.24 mg/kg). Also found in exhaust condensate of gasoline engines. Known to accumulate in the sediment and biota due to its tendency to adsorb strongly onto suspended particles. Its ultimate fate in sediments is believed to be biodegradation and biotransformation by benthic organisms, microbes and vertebrate organisms in the food chain.

ORGANOCHLORINES

Organochlorines are commonly associated with pesticides (i.e., insecticides, herbicides, as well as defoliants and growth regulators) and PCBs. All are toxic to some degree to invertebrates, fish, birds, mammals, and humans. Some are carcinogenic (cancer promoting). Although they have been released into the environment for decades, PCBs and most of the chlorinated pesticides have either been banned or severely limited in use during the past 15 years. Nevertheless, they continue to persist the environment. By virtue of their toxicity, carcinogenicity, and continued occurrence, PCBs, and pesticides such as DDT, chlordane, and toxaphene, are prominent and pivotal factors in decisions concerning the cleanup of contaminated sites.

oxychlordane, cis-nonachlor, alpha chlordane: constituents of chlordane, an insecticide. Wildlife and humans are easily poisoned by ingestion and inhalation.

oxychlordane, cis-nonachlor, alpha chlordane (continued): When heated to decomposition, it emits toxic fumes. It is highly toxic to fish. Animals poisoned by this and related compounds show marked loss of appetite and neurological symptoms.

Appendix D: Continued Profiles of contaminants of concern.

dieldrin: a prohibited insecticide in the U.S. that poisons by inhalation, ingestion, and absorption through the skin. It is more toxic than DDT by ingestion and skin contact and may accumulate in the body from chronic low dosages. There is sufficient evidence of carcinogenicity in animals. It, like chlordane, emits highly toxic fumes of chlorides and is highly toxic to fish.

total CL-4, -5, -6, -7, and -8 (PCB), total PCBs: congeners of PCBs. PCBs are persistent compounds which accumulate in food chains and the environment. They are toxic to aquatic organisms, wildlife and man. The skin, liver, gastrointestinal tract, and nervous system are sites of biological effects. Laboratory experiments, along with epidemiological studies of humans, have shown that the contaminant is carcinogenic. Humans and wildlife can be directly exposed to PCBs through ingestion of contaminated water or food, inhalation of PCB-contaminated particles or vapors, and absorption through the skin. In addition, offsite migration of PCB-contaminated material (via surface water runoff and leachate presents a potential hazard to both man and wildlife).

INORGANICS

Inorganics refer to compounds that do not contain carbon as the primary element; usually used as reference to metals and trace elements. Trace elements are essential and non-essential elements that typically occur in concentrations less than 1.0 ppm. For instance, cobalt, copper and zinc are believed essential to a healthy body, whereas forms of arsenic and lead are known to be extremely toxic. Heavy metals is a term generally used to define those metal and metalloid elements with a specific gravity greater than five (e.g., arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, zinc). They do not break down, although their chemical form will vary. They also are very persistent in the environment. Once absorbed, heavy metals stay in the body until excreted. Heavy metals are very dangerous contaminants, since they poison aquatic organisms even when present in comparatively low concentrations. Two metals have been identified as having no positive role in biological functioning: mercury, lead. In addition to their direct toxic effect, heavy metals produce dangerous, generation-skipping biological effects (mutagenic, embryotoxic) (Komarovskiy and Polishchuk 1981). Heavy metals accumulate in different parts of the food web which ultimately disturbs biotic cycles and destabilizes aquatic systems.

Appendix D: Continued Profiles of contaminants of concern.

<u>lead</u>: a biological nonbeneficial, non-essential element with the potential for high toxicity. Severe lead poisoning causes an array of effects on the central nervous system, the gastrointestinal system, the reproductive system and the kidneys. Bioaccumulation of lead has been demonstrated for a variety of organisms, but it is not biomagnified. Benthic microbes can methylate lead to form compounds which are volatile and more toxic than inorganic lead. Based on available information, fish accumulate very little lead in edible tissues.

<u>mercury</u>: a biological nonbeneficial, non-essential element with the potential for high toxicity. Mercury and its compounds each have different toxicological modes of action, depending on the molecular structure, stability in the organism, and routes of biotransformation and excretion. Organic mercury compounds (i.e., methylmercury) are more toxic than the inorganic forms. This is because the organic compounds dissolve readily in lipids and bond easily with proteins, thereby entering cells easily. Mercury is primarily removed from aquatic systems by adsorption onto the surfaces of particulates and subsequent settling to the bed sediment. There it is methylated by bacteria. Turbulence and/or the activity of benthic organisms then suspends this biologically available form into the water column. The average Hg concentration in soil is 0.03 ppm (Lindsay 1979). Mineral soils in the United States usually contain between 0.01 - 0.3 ppm Hg. Usually Hg levels in soils or sediments are considered significantly elevated if their concentration is >20 ppm; such concentrations are usually due to anthropogenic sources (Eisler 1987). Uncontaminated sediments are usually <1.0 ppm.

Appendix E. Action Levels : Metals

ELEMENT	CRITERIA[a]	
	Water[b]	Soil/Sediment[b]
Aluminum	400.0 (F);10.(M)	81000.(F)
Antimony	0.6 (F)	9.0
Arsenic	0.1 (F); 0.02 (M)	64.0
Barium	------	430.
Beryllium	50.0 (F)	15.0
Boron	12.0 (F)	100.
Cadmium	0.003 (F); 0.009 (M)	6.0 (F); 9.0 (M)
Chromium	0.03 (F); 1.2 (M)	37.0 (F); 128.(M)
Copper	0.01 (F); 0.005 (M)	310.
Lead	0.02 (F); 0.01 (M)	50.0 (F); 104.(M)
Manganese	7.0 (F); 2.0 (M)	1000.
Mercury	0.002 (F); 0.0003 (M)	20.0 (F); 1.0 (M)
Molybdenum	50.0 (F)	100.
Nickel	0.3 (F); 2.0 (M)	100.
Selenium	0.3 (F); 0.4 (M)	10.0
Silver	0.001 (F); 0.01 (M)	2.1
Tin (inorganic)	0.05 (F); 0.3 (M)	200.
(tributyl)	0.00001 (F)	---
Vanadium	1.0 (F); 1.0 (M)	150.
Zinc	20.0 (F); 5.0 (M)	200. (F); 267. (M)

[a] All concentrations are in ppm. Subjective criteria were chosen using best professional judgment after consulting references listed at the end of this appendix. In general, a sample value greater than 10 times a criterion can be cause for concern.

[b] (F) = freshwater; (M) = marine

Appendix F. Action Levels: Organochlorines - Soil/Sediment

Criterion for all compounds unless indicated otherwise:

Any organochlorine is not to exceed 10X background concentrations. If no background information is available, the concentrations are not to exceed 10X 1/2 the detection limit.

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Compounds	
chlordane & each isomer	
oxychlordane	
cis-nonachlor	
alpha chlordane	
gamma chlordane	
transnonachlor	
heptachlor & its metabolite heptachlor epoxide	
total DDT & each isomer	
o,p'-DDT	
p,p'-DDT	
o,p'-DDD	
p,p'-DDD	
o,p'-DDE	
p,p'-DDE	
hexachlorobenzene	
mirex	
dieldrin	
aldrin	
hexachlorocyclohexane (benzene hexachloride) & related compounds	
alpha BHC	
beta BHC	
lindane	
delta BHC	
toxaphene	
total PCBs	10 ppm urban areas; 25 ppm isolated areas.
total Cl-2	
total Cl-3	
total Cl-4	
total Cl-5	
total Cl-6	
total Cl-7	
total Cl-8	
total Cl-9	

Appendix G. Action Levels: Organochlorines - Shellfish

Compounds	Criteria[1/]
chlordane & each isomer oxychlordane cis-nonachlor alpha chlordane gamma chlordane transnonachlor	0.03 ppm (ww) (National Shellfish Sanitation Program).
heptachlor & its metabolite heptachlor epoxide	0.20 ppm (ww) (National Shellfish Sanitation Program).
total DDT isomers o,p'-DDT p,p'-DDT o,p'-DDD p,p'-DDD o,p'-DDE p,p'-DDE	1.5 ppm (ww) (National Shellfish Sanitation Program).
hexachlorobenzene	NTE 10X background levels (BL): No BL available then NTE 10X 1/2 detection level.
mirex	0.10 ppm (ww) (FDA criteria).
dieldrin	0.20 ppm (ww) (National Shellfish Sanitation Program).
aldrin	0.20 ppm (ww) (National Shellfish Sanitation Program).
hexachlorocyclohexane (benzene hexachloride) & related compounds alpha BHC beta BHC lindane delta BHC	0.20 ppm (ww) (National Shellfish Sanitation Program).
total PCBs total Cl-2 total Cl-3 total Cl-4 total Cl-5 total Cl-6 total Cl-7 total Cl-8 total Cl-9	NTE 10X background levels (BL): No BL available then NTE 10X 1/2 detection level.
toxaphene	5.0 ppm (ww) (FDA criteria).

Sum of aldrin, dieldrin, endrin, heptachlor and heptachlor epoxide:

1. "Alert" level if sum exceeds 0.20 ppm (ww).

2. Close shellfish bed if sum exceeds 0.25 ppm (ww)

1/ Criteria pertains to edible tissue only.

<u>Fish and Wildlife Service</u>
<u>Ecological Services Anchorage</u>
<u>Action Levels Bibliography</u>

Cleland, J. G. and G. L. Kingsburg. 1977. Multimedia Environmental Goals for Environmental Assessment. Vol II. MEG Charts and Background Information. EPA 600/7-77-1366. U.S. Environmental Protection Agency, Washington, D.C.

Day, John W., Jr., Hall, C. A., Kemp, W. M. and A. Yanez-Arancibia. 1989. <u>Estuarine Ecology</u>. John Wiley and Sons, New York. 543 pp.

Edwards, N. T. 1983. Polycyclic aromatic hydrocarbons (PAH's) in the terrestrial environment - a review. Journal of Environmental Quality. 12(4):427-441.

Eisler, R. 1989a. Molybdenum Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.19). Patuxent Wildlife Research Center, Laurel, Maryland. 61 pp.

Eisler, R. 1989b. Tin Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.15). Patuxent Wildlife Research Center, Laurel, Maryland. 83 pp.

Eisler, R. 1988. Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.12). Patuxent Wildlife Research Center, Laurel, Maryland. 92 pp.

Eisler, R. 1987a. Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.14). Patuxent Wildlife Research Center, Laurel, Maryland. 134 pp.

Eisler, R. 1987b. Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.10). Patuxent Wildlife Research Center, Laurel, Maryland. 90 pp.

Eisler, R. 1987c. Polycyclic Aromatic Hydrocarbon Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.11). Patuxent Wildlife Research Center, Laurel, Maryland. 81 pp.

Eisler, R. 1986a. Chromium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.6). Patuxent Wildlife Research Center, Laurel, Maryland. 60 pp.

Eisler, R. 1986b. Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.7). Patuxent Wildlife Research Center, Laurel, Maryland. 72 pp.

Eisler, R. 1985a. Cadmium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.2). Patuxent Wildlife Research Center, Laurel, Maryland. 46 pp.

Eisler, R. 1985b. Mirex Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.1). Patuxent Wildlife Research Center, Laurel, Maryland. 42 pp.

Eisler, R. 1985c. Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.5). Patuxent Wildlife Research Center, Laurel, Maryland. 57 pp.

Eisler, R. 1985d. Toxaphene Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service Biological Report 85(1.4). Patuxent Wildlife Research Center, Laurel, Maryland. 26 pp.

Farm Chemicals 1989. Farm Chemical Handbook. Meister Publishing Company, Willoughby, Ohio. 375 pp.

Fortescue, J. A. C. 1980. Environmental Geochemistry: A Holistic Approach. Springer - Verlag, New york. 347 pp.

Furness, R. W., and P. S. Rainbow (Eds.). 1990. Heavy Metals in the Marine Environment. CRC Press, Inc. Boca Raton, Florida. 256 pp.

Goldschmidt, V. M. 1954. Geochemistry. Clarendon Press, Oxford. 234 pp.

Gough, L. P., Severson, R. C. and H. T. Shacklette. 1988. Element Concentrations in Soils and Other Surficial Materials of Alaska. U.S. Geol. Survey Prof.Paper 1458. 53 pp.

Gough, Larry P., H. T. Shacklette, and A. A. Case. 1979. Element concentrations toxic to plants, animals, and man. Geol. Survey Bull. 1466. U.S. Govt. Printing Office. 80 pp.

Hem, J. 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. U.S. Geological Survey Water-Supply Paper 2254. Alexandria, VA. 263 pp.

Jenkins, D. W. 1980a. Biological Monitoring of Toxic Trace Metals. Volume I, Biological Monitoring and Surveillance. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-089, NTIS PB81-103475. September. 215 pp.

Jenkins, D. W. 1980b. Biological Monitoring of Toxic Trace Metals. Volume 2, Toxic Trace Metals in Plants and Animals of the World. Part I. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-090, NTIS PB81-103483. September. 503 pp.

Jenkins, D. W. 1980c. Biological Monitoring of Toxic Trace Metals. Volume 2, Toxic Trace Metals in Plants and Animals of the World. Part II. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-091, NTIS PB81-103491. September. 478 pp.

Jenkins, D. W. 1980d. Biological Monitoring of Toxic Trace Metals. Volume 2, Toxic Trace Metals in Plants and Animals of the World. Part III. U.S. EPA Office of Research and Development. Las Vegas, NV. EPA-600/3-80-092, NTIS PB81-103509. September. 290 pp.

Johnson, W., and M. Finley. 1980. Handbook of Acute Toxicity of Chemicals to Fish and Aquatic Invertebrates. U.S, Fish and Wildlife Service, National Fisheries Research Laboratory, Columbia, Missouri. Resource Pub. 137. 98 pp.

Jones, K., Stratford, J., Waterhouse, K. and N. Vogt. 1989. Organic contaminants in Welsh Soil: Polynuclear Aromatic Hydrocarbons. Environ. Sci. Technol. 23:540-550.

Komarovskiy, F. and L. Polishchuk. 1982. Mercury and other heavy metals in the water: migration, accumulation, and toxicity to aquatic organisms (a review). Hydrobiological Journal 5:51-62.

Lindsay, W. 1979. Chemical equilibra in soils. John Wiley and sons, New York. 449 pp.

Long, Edward R. and L. G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program. NOAA Tech. Mem. NOS OMA 52. 175 pp.

Malins, D. (editor) 1977. Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Volume II. Biological Effects. Academic Press, Inc. New York, NY. 477 pp.

Mance, Geoffery. 1987. <u>Pollution Threat of Heavy Metals in Aquatic Environments</u>. Elsevier Applied Science, London. 363 pp.

McErlean, A. and T. Duke. 1981. On the use of indices in aquatic toxicological hazard assessment. Regulatory Toxicological and Pharmacological. 1:344-354.

Mearns, A., Matta, M., Simecek-Beatty, D., Buchman, M., Shigenaka, G. and W. Wert. 1988. PCB and Chlorinated Pesticide Contamination in U.S. Fish and Shellfish: A Historical Assessment Report. NOAA Technical Memorandum NOS OMA 39. Seattle, WA. February. 140 pp.

Menzie, C. 1980. Metabolism of Pesticides, Update III. U.S. Fish and Wildlife Service, Special Scientific Report - Wildlife No. 232. Washington, D.C. 709 pp.

National Academy of Sciences and National Academy of Engineering. 1972. Water quality and criteria. A report of the Committee on Water Quality Criteria, Environmental Studies Board. EPA R3-73-003. March, 1973. PB 236-199/6BA.

National Research Council of Canada. 1983. Polycyclic Aromatic Hydrocarbons in the Aquatic Environment: Formation, Sources, Fate and Effects on Aquatic Biota. Panel on Polycyclic Aromatic Hydrocarbons Subcommittee on Water. Pub. No. NRCC 18981 of the Environmental Secretariat. Ottawa, Canada. 209 pp.

Olsen L. and K. Adams. 1984. Effects of Contaminated Sediment on Fish and Wildlife: Review and Annotated Bibliography. U.S. Fish and Wildlife Service. Washington, D.C. FWS/OBS-82/66 April 103 pp.

Pavlou, Spyros P. 1987. The use of the equilibrium partitioning approach in determining safe levels of contaminants in marine sediments. Chap. 25 in Dickson, K. L., Maki, A. W. and W. A. Brungs (Eds.), Fate and Effects of Sediment-Bound Chemicals in Aquatic Systems. Pergamon Press, New York. 447 pp.

Phillips, D. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments - a review. Environ. Pollut. 13: 281-317.

Phillips, D. 1980. Toxicity and Accumulation of Cadmium in Marine and Estuarine Biota. Chap. 12 in J. Nriagu (Ed.) Cadmium in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.

Santodonato, J., Howard, P. and D. Basu. 1981. Health and Ecological Assessment of Polynuclear Aromatic Hydrocarbons. Center for Chemical Hazard Assessment. Pathotox. Pub., Park Forest South, Illinois 364 pp.

Sax, N. 1987. Hazardous Chemicals Information Annual, No. 2. (Editor) Van Nostrand Reinhold Co., New York. 707 pp.

Sax, N. 1986. Hazardous Chemicals Information Annual, No. 1. (Editor) Van Nostrand Reinhold Co., New York. 766 pp.

Sax, N. and R. Lewis. 1987. Hazardous Chemicals Desk Reference. Van Nostrand Reinhold Co., New York. 1084 pp.

Shea, D. 1988. Developing national sediment quality criteria. Environ. Sci. Technol. 22(11): 1256 - 1261.

Smith, J., Harte, P. and M. Hardy. 1989. Trace-metal and organochlorine residues in sediment of the upper Rockaway River, New Jersey. Bull. Environ. Contam. Toxicol. 39:465-473.

Soholt, L., Harris, V., Knight, M., Siskind, B. and D. Wyman. 1981. Coal Combustion Waste Manual: Evaluating Impacts to Fish and Wildlife. U.S. Fish and Wildlife Service, Biological Services Program, National Power Plant Team, FWS/OBS-81/05. 150 pp.

Stokes, P. 1979. Copper Accumulations in Freshwater Biota. Chap. 12 in J. Nriagu (Ed.) Copper in the Environment, Part 1: Ecological Cycling. John Wiley and Sons, Inc., New York.

Tetra Tech, Inc. 1989. Work Plan. Remedial Investigation/Feasibility Study, Naval Air Station Adak, Adak Island, Alaska. Prepared for U.S. Navy Engineering Field Activity, Northwest, Naval Facilities Engineering Command, Silverdale, Washington. October. 114 pp.

U.S. Environmental Protection Agency. 1986a. Superfund Public Health Evaluation Manual. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/1-86/060 October. 175 pp.

U.S. Environmental Protection Agency. 1986b. Hazardous Waste Land Treatment. Municipal Environmental Research Laboratory. Office of Research and Development. Cincinnati, Ohio. Pub. SW-874. April. 671 pp.

U.S. Environmental Protection Agency. 1980a. Ambient Water Quality Criteria for Acenaphthene. Office of Water Regulations and Standards. EPA 440/5-80-015, NTIS PB81-117269. October. 38 pp.

U.S. Environmental Protection Agency. 1980b. Ambient Water Quality Criteria for Aldrin/Dieldrin. Office of Water Regulations and Standards. EPA 440/5-80-019, NTIS PB81-117301. October. 145 pp.

U.S. Environmental Protection Agency. 1980c. Ambient Water Quality Criteria for Chlordane. Office of Water Regulations and Standards. EPA 440/5-80-027, NTIS PB81-117384. October. 59 pp.

U.S. Environmental Protection Agency. 1980d. Ambient Water Quality Criteria for DDT. Office of Water Regulations and Standards. EPA 440/5-80-038, NTIS PB81-117491. October. 163 pp.

U.S. Environmental Protection Agency. 1980e. Ambient Water Quality Criteria for Heptachlor. Office of Water Regulations and Standards. EPA 440/5-80-052, NTIS PB81-117632. October. 106 pp.

U.S. Environmental Protection Agency. 1980f. Ambient Water Quality Criteria for Fluoranthene. Office of Water Regulations and Standards. EPA 440/5-80-049, NTIS PB81-117608. October. 76 pp.

U.S. Environmental Protection Agency. 1980g. Ambient Water Quality Criteria for Naphthalene. Office of Water Regulations and Standards. EPA 440/5-80-059, NTIS PB81-117707. October. 67 pp.

U.S. Environmental Protection Agency. 1980h. Ambient Water Quality Criteria for Polychlorinated Biphenyls. Office of Water Regulations and Standards. EPA 440/5-80-068, NTIS PB81-117798. October. 190 pp.

U.S. Environmental Protection Agency. 1980i. Ambient Water Quality Criteria for Polynuclear Aromatic Hydrocarbons. Office of Water Regulations and Standards. EPA 440/5-80-069, NTIS PB81-117806. October. 191 pp.

U.S. Environmental Protection Agency. 1980j. Ambient Water Quality Criteria for Toxaphene. Office of Water Regulations and Standards. EPA 440/5-80-076, NTIS PB81-117863. October. 190 pp.

U.S. Environmental Protection Agency. 1979a. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. Halogenated Aliphatic Hydrocarbons, Halogenated Ethers, Monocyclic Aromatics, Phthalate Esters, Polycyclic Aromatic Hydrocarbons, Nitrosamines, and Miscellaneous Compounds. Office of Water Planning and Standards, Washington D.C. EPA-440/4-79-029b. December.

U.S. Environmental Protection Agency. 1979b. Water-Related Environmental Fate of 129 Priority Pollutants. Volume I. Introduction and Technical Background, Metals and Inorganics, Pesticides and PCBs. Office of Water Planning and Standards, Office of Water and Waste Management. Washington D.C. EPA-440/4-79-029a. NTIS PB80-204373. December. 400 pp.

U.S. Environmental Protection Agency. 1979c. Water-Related Environmental Fate of 129 Priority Pollutants. Volume II. Halogenated Aliphatic Hydrocarbons, Halogenated Ethers, Monocyclic Aromatics, Phthalate Esters, Polycyclic Aromatic Hydrocarbons, Nitrosamines, and Miscellaneous Compounds. Office of Water Planning and Standards, Office of Water and Waste Management. Washington D.C. EPA-440/4-79-029b. NTIS PB80-204381. December. 500 pp.

U. S. Environmental Protection Agency. 1976. Quality Criteria for Water. EPA 440/9-76-023.

U.S. Department of Health and Human Services. 1989. Fifth Annual Report on Carcinogens, Summary. National Toxicology Program. National Institute of Environmental Health Sciences. Research Triangle Park, North Carolina. NTP 89-239. 340 pp.

U.S. Food and Drug Administration. 1980. Action Levels for Poisonous or Deleterious Substances in Human food and Animal Feed. Washington, D.C. 35 pp.

Verschueren, K. 1983. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Co., New York. 1310 pp.

41 pgs.

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gif ID Numbers

rpt#	gif#	page #
RPT 00222. TXT	<00222001.gif>	Fig. 1
	<00222002.gif>	Fig. 2
	<00222003.gif>	Fig. 3
	<00222004.gif	Fig. 4
	<00222005.gif>	Appendix A
	<00222006 gif>	Appendix A-(Cont.)
	<00222007gif>	Appendix B
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